The Arctic and World Ocean: Current State, Prospects and Challenges of Hydrocarbon Resources Development

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Abstract

The report provides information on the current state and prospects of oil and gas resources development in the major offshore oil and gas basins of the World, including the Arctic. Considered the most important achievements and negative results of offshore oil and gas industry in the last decade. Illustrates the main trends of the offshore oil and gas production volume in the Arctic and the World Ocean in comparison with trends of the unconventional hydrocarbons production. It is shown that Russia is the leader in terms of hydrocarbons production, both the Arctic onshore and offshore.

Provides information on the geological and geophysical study density of the Arctic waters and the current state of the geophysical and drilling fleets of Russia. The analyses of the petrophysical and thermobaric conditions studies at big depths are presented. Shows a great role of abnormally high reservoir pressures (AHRP) to maintain industrial reservoirs, which significantly increases the hydrocarbon resources of the Arctic region. It is proved that Russia is the leader in the Arctic hydrocarbon reserves and resources. Advices on selecting priority projects for the development on the Arctic offshore are given.

Particular attention is paid to natural and man-made problems of the offshore oil and gas resources development, including AHRP, permafrost, gas pockets and gas hydrates. It is shown that the waters of five countries in the Arctic region is not enough studied to start a large-scale oil and gas fields development. The best results of the Arctic oil and gas resources studies and developments with the preservation of its ecosystem can only be achieved through international cooperation.

Keywords: Arctic Ocean, Barents and Kara seas, hydrocarbons, oil and gas, Russia offshore production, abnormally high reservoir pressures.

The growth of world's need in hydrocarbon fuel and depletion of its onshore reserves has activated the exploration in offshore areas of the Arctic and World Ocean, resulted in long-range growth of onshore oil and gas production. There is reducing of hydrocarbon (HC) production in many old oil and gas bearing basins (the Gulf of Mexico – the USA and Mexico, the North Sea – all countries). In world practice, a serious increase in exploration drilling led to the discovery of many large onshore and offshore oil and gas bearing basins and fields, including the Arctic offshore (Fig.1). A diligent work in the exploration for oil and gas fields in "unconventional" complexes of rocks (tight, shale, coalbed hydrocarbon reservoirs) and in conditions of high pressure and high temperature (HPHT) are conducted.

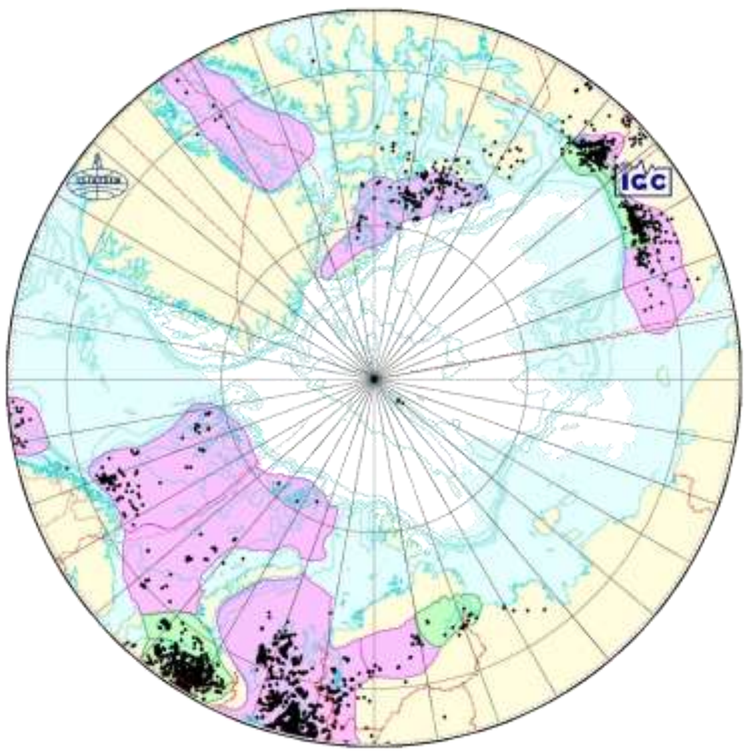

Figure 1. The Arctic oil and gas bearing basins.

The specificity of Russia's natural, climatic and geological conditions is that the most resource-rich areas are located in the Arctic and sub-Arctic regions. About two thirds of the Russian area is featured with the presence of permafrost, which also covers a substantial part of the Arctic sea waters complicating the development of hydrocarbon (HC). Recoverable oil and gas resources of the Russian Arctic shelf comprise 90% of the resources of all offshore, estimated to be 100 billion tones OE. The distribution of HC resources in the Russian waters is highly uneven: about 75% of total resources and 86% of northern seas' resources are concentrated in the Barents, Pechora and Kara seas. This depends to a great extent on regional geological features and large area of these waters (a total of about 50% of the Russian Arctic shelf). Oil and gas pools over a wide stratigraphic range (including Silurian and Ordovician) have been discovered in the Barents and Kara onshore and offshore region. All the Arctic offshore fields have also been discovered in those seas. None of the oil and gas wells have been drilled so far in the eastern Arctic seas of Russia (Laptev, East Siberian and Chukchi seas).

As for early 2014 there are total 113 license blocks in the Russian offshore (67 in the Arctic) with total area 1.75 sq km. Rosneft and Gazprom having accordingly 40.5 and 34.9 % of all Russian licenses (1.64 sq km or 94% of total licensed area) are the principal owners of the license areas in the Arctic and other seas of Russia. In 2011–2013 Russian majors created alliances with several foreign companies (ExxonMobil, ENI, Statoil, Total, SNPC) for cooperative study and development of oil-and-gas-bearing of license areas. The BP company is participating too, owning Rosneft's big package of shares.

More than 250 thousand km of the CDP (Common Depth Point) seismic lines were acquired and 34 exploration wells were drilled in 2000-2013 in the Arctic Shelf of Russia (Fig.2). The gross reserves additions HC are more than 2 billion tons OE.

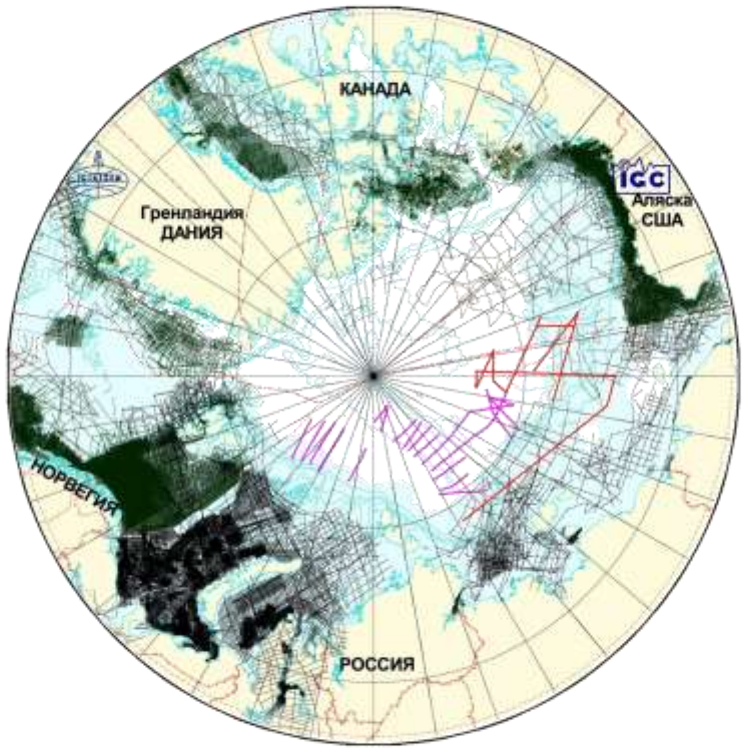

Figure 2. The Arctic Common Depth Point 2D seismic lines location (01.06.13).

Four Russian geophysical companies have fleet of 13 research vessels with advanced seismic exploration equipment of foreign manufacture. In addition there are many companies engaged in works in offshore-onshore transition zones and equipped with modern geophysical equipment of the Russian and foreign manufacture as well as small shallow water vessels. However there are serious problems with drilling rigs capacities.

The first gas production from the Russian Arctic onshore fields started in the north of Krasnoyarsk District at the Messoyakha gas field in 1969. In 1972, gas production started in the Yamal-Nenets Autonomous District (YaNAO) at the Medvezhie field with further transportation to European Russia and Europe. Thus, the Russian Arctic oil and gas transportation system started working 5–8 years earlier than that in Alaska through the Trans-Alaska Pipeline built in 1977 to transport oil from the Alaska North Slope fields (area of the Prudhoe Bay Unit) to the port of Valdez in the south of Alaska. On October 23, 2012, gas transportation started from the unique reserves Bovanenkovskoye gas condensate field owned by Gazprom through a new main gas pipeline Yamal-Ukhta with a diameter of 1,420 mm and length of about 1,100 km. The maximum planned production level of this field will amount to 115–140 billion cubic meters. For four decades in the YaNAO, over 16 trillion cubic meters of gas have been produced and transported westward, nearly a half of which was produced to north from the Polar Circle. The total amount of produced and transported Arctic (to the north of the Polar Circle) HCs of oil equivalent is 3.5 times as much as that produced on the Alaska North Slope, Canada and Norway Arctic areas. Oil and gas production in the Arctic has long been the basis of economic development of domestic regions, e.g., Alaska, Yamal-Nenets and Nenets autonomous districts reaching in the above two Russian regions, according to the local administration data, up to 83 and 98%, respectively.

However, HC resources on the Arctic shelf and, moreover, on the Arctic Ocean continental slope are being developed much slower than in most other regions of the World Ocean, which is mainly due to extremely difficult nature an climatic conditions, environmental vulnerability and (to a lesser extent) due to the presence of disputable offshore areas in the Circum-Arctic region.

Oil production in the Russian Arctic offshore is going from two fields – Yurkharovskoye (since 2003) and Prirazlomnoye (since December 2013). Yurkharovskoye oil and gas-condensate field is located in the Taz Bay of the Kara Sea shallow water (YaNAO). Drilling of the development wells on the offshore part of the field is conducted from shore by deviated wells with horizontal ending (ERD like in Alaska and Sakhalin); meanwhile the horizontal displacement of wellbores is 3–5 km, and the gas production rates from the Valanginian pools – 3–5 million cubic meters per day. Thanks of the Yurkharovskoye field HC production Russia is a leader of the world's Arctic offshore marketable HC production since 2005 (Fig.3).

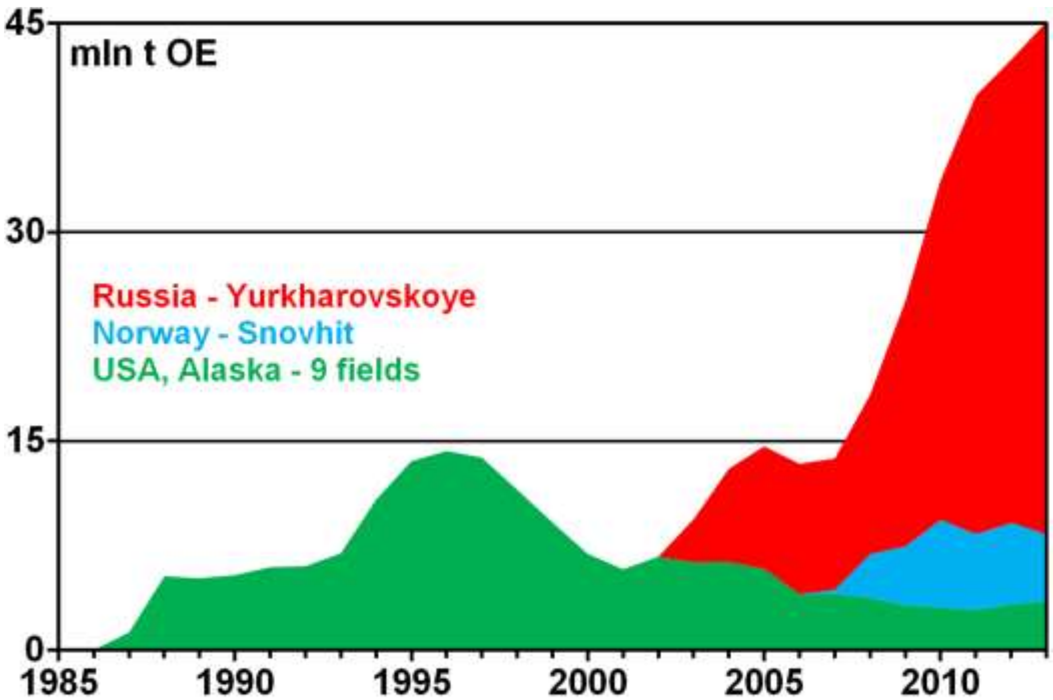

Figure 3. Arctic offshore marketable HC production.

Development of Prirazlomnoye Oil Field is organized by Gazprom from an offshore ice-resistant fixed platform (OIRFP), which has a 126x126 m steel caisson support base and a total operational weight of 506 thousand tons, including ballast. The field development is planned under the project comprising the drilling of about 40 differently directed deviated wells (ERD) with horizontal tailing-in (vertical depth – 2,400 m), including 19 operational and 16 water injection ones. A separate well is intended to pump drilling waste into the Triassic sands. There will be the use of up to 95% of associated gas for own needs.

Russian private company Lukoil constructed in the Pechora Sea a unique fixed offshore ice-resistant off-loading oil terminal (FOIROT) Varandey to export oil from the Timan-Pechora Province under the Northern Territories Project, which is operated year round and is the world's northernmost oil terminal (69°05'N) to be listed in the Guinness Book of Records.

OGRI RAS has engaged development of new seismic 2D-4D technologies and in wide-ranging complex research of the Arctic region's oil and gas bearing using 3D modeling of various characteristics of environmental conditions, including organic maturity and thermobaric. The main objectives of this work are the following: increase in the reliability of predicting oil and gas bearing zones; determining undiscovered hydrocarbon accumulations as a result of the usage of heavy drilling mud; predicting accumulations below the TD of wells; optimization of the drilling process and reduction in the number of well accidents.

The analysis of the petrophysical and thermobaric conditions at large depths are presented. Many of them are abnormally high reservoir pressure (AHRP), exceeding hydrostatic gradient by 1.5-2 times. Modeling was conducted at local and regional levels. During modeling for the Southern Kara Region abnormal zones of formation temperatures and pressures at different levels were determined. The unique, closely situated Bovanenkovskoye, Kharasaveyskoye and Kruzenshternskoye gas condensate fields are located in the strongest abnormal zone on area 60x100 km, with total reserves of over 10 billion tn OE. Here AHRP is present in the Lower Cretaceous deposits (1.8-2 km), while it is present regionally in Yamal-Gydan essentially in the Jurassic. Lower Cretaceous deposits of Leningradskoye and Rusanovskoye gas condensate fields have AHRP at depths more than 2 km, abnormal factors Ka reach 1.24 at TD of wells (2,500 m).

Shows a great role of AHRP to maintain industrial reservoirs, which significantly increases the HC resources of the Arctic region. Reservoir properties analyses in dependency from bed pressure have being made for the Western Siberia northern part onshore-offshore fields (Bovanenkovskoye, Kharasaveyskoye, Large Urengoy, Yamburg, Rusanovskoye, Leningradskoye, new fields in the Ob and Taz bays of the Kara Sea and etc) showed that AHRP preserves good open porosity of rocks (about 15%) in deep deposits (3-5 km) of the Lower Cretaceous and Jurassic (Fig.4). The same situation take place even in very deep Jurassic-Permian deposits (e.g. at 5-8 km) in En-Yakhinskaya-7 and Tyumenskaya-6 super deep wells (Fig.4).

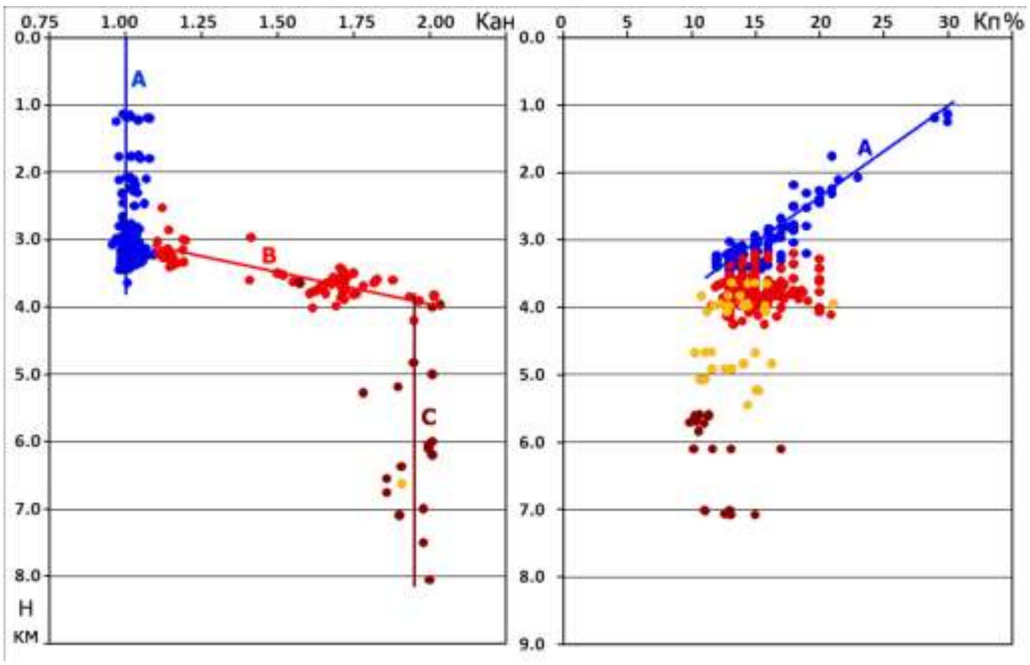

Figure 4. Large Urengoy: abnormal pressure factors coefficient (Ka) and porosity (Kp).

Modeling of thermobaric conditions at the local level were conducted for the Murmanskoye Gas field, which has the greatest number of wells (9) drilled of any offshore field in the Russian Arctic Regions. In the Murmanskoye field area, formation pressure gradients from sea-bottom to the Upper Triassic at depths of 2,200-2,300 m are close to hydrostatic (1-5 %). Since there was a smooth, almost linear increase of formation pressure with depth, a maximum measured value of 80.9 MPa at a depth of 4,210 m in well 24 (abnormal factor Ka=1.96) was observed. Such distribution of formation pressures testifies to possible migration of gas from deeper deposits through systems of sub-vertical fractures and faults to the Upper Triassic - Jurassic clay seal. A positive closed temperature anomaly was determined along horizontal trends of formation temperatures at a level about of 3 km and deeper around the structure's arch (the centre of the gas accumulations). The closed pressure anomaly starts to form at depths over 3 km (below the location of gas accumulations) and shows a strong presence at a depth of 3.5 km. There is a basis to assume the presence of additional undiscovered oil and gas accumulations in the Triassic and Upper Paleozoic complexes.

Therefore, the formation of "closed systems" with AHRP is possible if good regional seals are present. AHRP protects liquid hydrocarbons from destruction despite extreme high temperature that falls outside the limits of the traditional "oil window". Deep deposits of the Russian Arctic could well have a huge hydrocarbon potential and valid leads should be considered as potentially promising targets for future oil and gas exploration.

In a result of our mega-regional studies it is received that the offshore areas of the Western Arctic of Russia contain 43.1% of liquid hydrocarbon reserves and 91.3% of gas reserves of all Arctic Shelf (five countries) in spite of the fact that all Arctic seas of Russia are poorly studied by seismic survey and drilling (Fig.5). The given situation allows to confirm, that maximum reserves growth and discovery of new large-scale fields in wide stratigraphic level of deposits (from the Paleozoic to Cenozoic including) is mainly possible in the Russian shelf. Additionally by studying of regional seismic data we see high of the Arctic deep water areas.

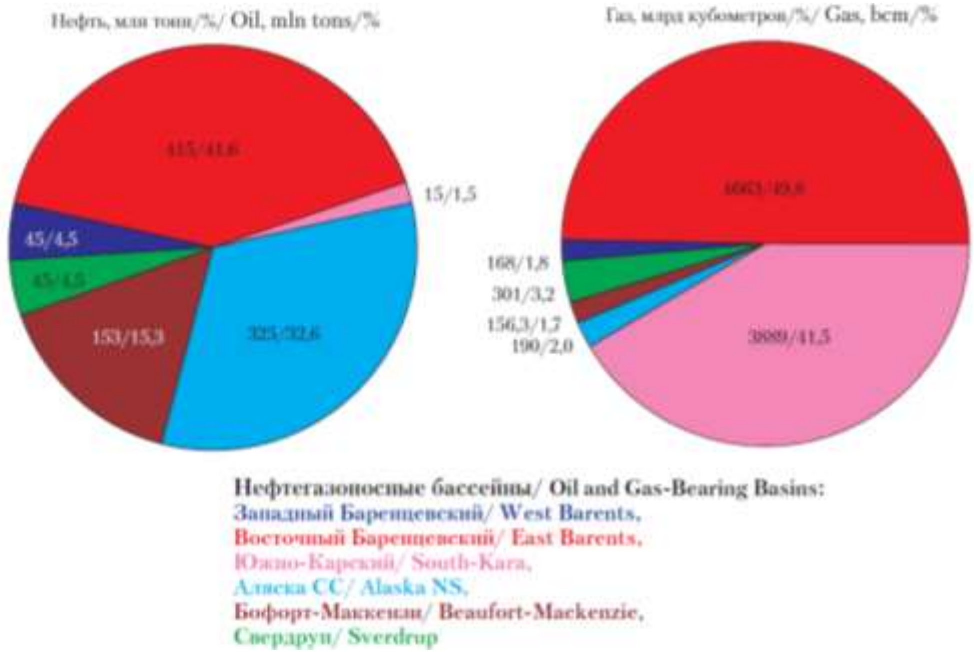

Figure 5. Oil and Gas Reserves in the Arctic Shelf (2012).

In all our studies particular attention is paid to natural and man-made challenges of the offshore HC resources development, including AHRP, submarine permafrost, gas pockets and gas hydrates. As a result of studying it is possible to see that all offshore areas of five countries in the Arctic region are not enough studied to start a large-scale oil and gas fields development.

In the conclusion we would like to note followings:

1. Pursuant to the experience of Russia and the USA it is reasonable to choose the top priority fields for organization of the offshore oil and gas fields under the Arctic conditions nearby the seashore with widely developed infrastructure. Fields which can be developed by horizontal wells (ERD) from shore are of particular interest. This approach is successfully tested in the USA and Russia and it is the safest for the fragile environment of the Arctic shelf.

2. Many Russian technological solutions on hydrocarbon exploration, production and transportation have no analogs in the World. We ought not to forget that just Russia has and successfully uses more than 50 years the unique powerful nuclear icebreaking fleet.

3. Statements of some experts about backlog of Russia in development of hydrocarbon resources in the Arctic are unfounded. Russia is a leader in hydrocarbon reserves and resources as well as the extent of its onshore and offshore production in the Arctic. Besides, Russia has great hydrocarbon reserves and resources in various regions; therefore, it can begin the large-scale development of the offshore fields in the Arctic by easy stages choosing the best and the safest innovative technologies, protecting strategic reserve of hydrocarbons and fragile environment of the Arctic for the future generations.

4. The best results of the Arctic oil and gas resources studies and developments with the preservation of its ecosystem can only be achieved through international cooperation.